Sediment Dispersal from a Kimberlite Intrusion in Elliott County, Kentucky

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Geology 570

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Abstract

Sediments being transported by streams away from the kimberlite intrusions in Elliott County, Kentucky appear in a characteristic pattern of accumulation which is controlled by the grain size of the sediments and the discharge of the streams. Hamilton Creek has been measured at two points of significance and found to have discharges of 0.414 cubic feet per second and 0.660 cubic feet per second farther downstream. These discharges correspond to seven sediment dispersal patterns of the kimberlite minerals ilmenite, garnet, and diopside in grain sizes of 0.061 mm., 0.125 mm., and 0.250 mm. Similar patterns were established for the same minerals, in the same size range, in Ison Creek. Factors such as the possible addition to the stream of the same minerals from kimberlite outcrops of lesser importance were found to have no noticeable effect on the patterns. Other factors, such as the possible superpositioning of a recent pattern on an older Pleistocene pattern were examined. If this is true, then the recent pattern has almost entirely obliterated the older pattern. Accurately defined patterns, when allied with discharge measurements for any stream, could be a good prospecting tool to help find more kimberlite intrusion outcrops.

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Location and Description of Area

The point source of sediments used in this investigation is located near Stephens, in Elliott County, Kentucky, in the northeastern portion of the state. More precisely, Stephens, which is centrally located in the area of study, is at 82 degrees 57 minutes 30 seconds West longitude and 38 degrees 08 minutes 07 seconds North latitude. The term "point source" is used to distinguish the source from a widely outcropping bed which contributes sediments from a large area of exposure, rather than from a few isolated outcrops. There are actually two main point sources contributing heavy minerals to the stream sediments. One of these is located 2.03 miles in a direction south 76° west from the intersection of Ky. 486 and Ky. 409 in the valley of Ison Creek. The other is located 1.27 miles in a direction south 62.5° west from the same intersection in the valley of Hamilton Creek. Two other exposures of kimberlite, the source material, occur in tributary valleys of the Ison Creek main valley. They are located 1.89 miles in a direction south 73.5° west, and 1.20 miles in a direction south 75° west from the Ky. 486 and Ky. 409 intersection. The main outcrop of kimberlite in what will be called, for convencience, Ison Creek Valley is situated in a tributary valley and is approximately 440 feet from Ison Creek. The two outcrops of lesser importance in the Ison Creek Valley are situated well up into their respective valleys and material from each of them must travel about 0.25 miles to reach Ison Creek. The second main outcrop in what will be called the Hamilton Creek Valley is 0.21 miles up a tributary valley of the Hamilton Creek Valley.

The area, in general, is one of uneven topography consisting of steep-sided hills, which have been highly eroded, and level floodplains in the valleys (Fig. 1). The relief in the work area, as shown in Plate 1, is 460 feet. Most of

Fig. 1. Local topography as seen in Hamilton Creek Valley.

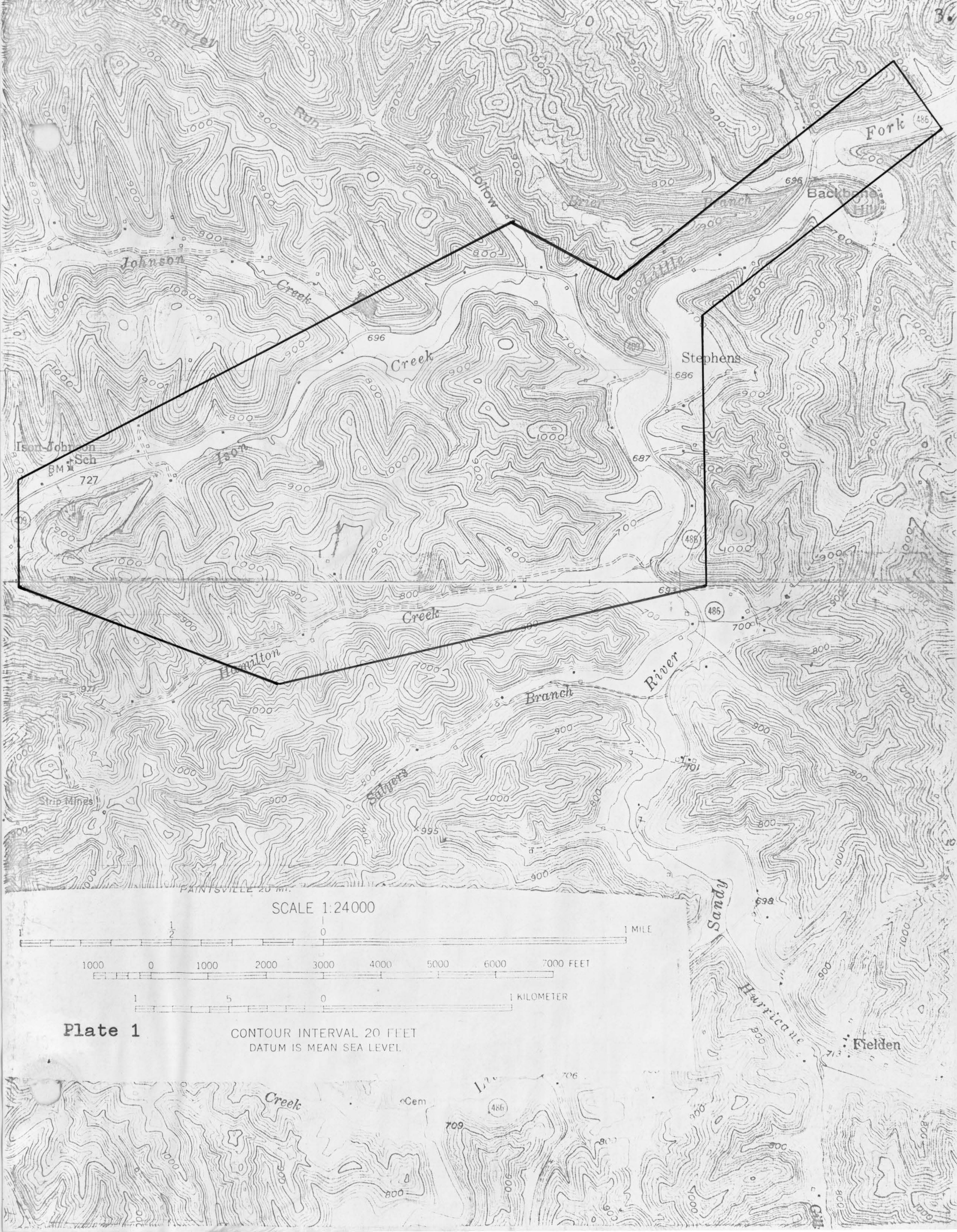

Squirrel
Run
Hollow
Brier
Branch
Fork
486
Backbone
Hill
Little
Johnson
Creek
696
Creek
Stephens
686
687
Ison-Johnson
Sch
BM
727
Ison
693
486
700
Creek
Hamilton
River
Branch
Salyers
Strip Mines
x995
Sandy
698
Hurricane
713
Fielden
Creek
Cem
709
706
SCALE 1:24000
1
1/2
0
1 MILE
1000
0
1000
2000
3000
4000
5000
6000
7000 FEET
1
.5
0
1 KILOMETER
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Plate 1

the small tributary valleys have a high gradient and a V-shaped profile from their heads to their mouths. They are apparently the result of actively downcutting ephemeral streams. The large valleys, such as Ison Creek Valley, Hamilton Creek Valley, and the valley of the Little Fork of the Little Sandy River, are in a more mature stage than the small tributary valleys. Floodplains in the large valleys range from a few hundred feet wide in Ison Creek and Hamilton Creek Valleys to 0.20 miles wide in the valley of the Little Fork of the Little Sandy River.

There is evidence that the area had, at one time, a periglacial climate. It seems odd, at first glance, that streams such as Hamilton Creek and Ison Creek, which at points deteriorate into almost stagnant marsh water or disappear altogether beneath the heavy marsh vegetation, could have cut through 400+ feet of bedrock, and then, through their own lateral migrations, have widened the valley floors and created the large floodplains which presently exist. If, however, the streams were not always as small and poorly defined as they are today, this would be easily conceivable.

Physical evidence of a periglacial climate exists in the well defined solifluction patterns on the hillsides (Fig. 2). Sometimes called "steps", these structures appear on almost every hillside, regardless of the vegetation cover. This suggests that they were formed before the existence of the present vegetation patterns, which could have caused the downhill creep to have greatly varied its patterns and extent.

The knowledge that the area was, in fact, not very far

Fig. 2. Effects of solifluction on a hillside in Hamilton Creek Valley - evidence of a periglacial climate.

south of the farthest extent of the Pleistocene continental glaciers lends support to the belief that a periglacial climate existed there during the Pleistocene glaciations.

The preceding discussion on the probable existance of a periglacial climate in the area is extremely important for a complete analysis of the results of the sediment dispersal from the point source study, which will follow in a later section. It must be noted that if the wide floodplains were largely the result of larger streams that existed in the Pleistocene, then much of the heavy minerals may be in their present location in the streambeds because they were transported most of the way there by Pleistocene streams. It is possible that the present streams have picked up the heavy minerals from the floodplains where they were deposited by the larger streams. It is also possible that the kimberlite intrusions were not exposed by erosion before or during the Pleistocene and that the heavy minerals grains were deposited in their present location in the streambeds solely by the present streams and the downslope movement, runoff, and ephemeral streams which supply the main streams with the sediments. If the latter case is true, then the sediment dispersal patterns discerned from this study can be taken at face value and be directly related with the flows and available transporting energy which now exists in the area's streams. However, If this is not the case and a periglacial climate did cause larger streams and a higher erosive force, then the true value of the dispersal patterns and their erosive relations to the present streams is tempered to a discussion of sediments which have been reworked into the present patterns along with a supply of new sediments.

Local Rocks

The rocks that make up the hills in the area of Stephens, Kentucky belong to the Breathitt Formation. This consists of Lower and Middle Pennsylvanian cyclothems in its bottom half and thick sequences of sandstone and shale or mudstone in its upper half. None of the rocks from this formation that outcropped in the Ison Creek or Hamilton Creek Valleys contained any of the heavy minerals ilmenite, garnet, or diopside to the extent that they were identifiable in a hand specimen. Therefore, it is safe to conclude that any ilmenite, garnet, or diopside grains found in stream sediment samples have come from the kimberlite point sources.

The kimberlite sources, themselves, are intrusive bodies thought to be radiating fingers, near the surface, of a single intrusive body at depth. A discussion of the exact mineralogy of the intrusion is not essential to this study. It will suffice to say that three of the minerals found in the intrusive bodies are also found and easily identified in the stream sediments of the area. These minerals are ilmenite, garnet, and diopside. Each is easily distinguished from the other minerals in the stream sediment suite and is, therefore, an excellent mineral to use in the study of sediment dispersal from the point sources. The diopside ranges in color from almost white to light green, the color deepening with an increase in iron as the mineral approaches the composition of hedenbergite $CaFe(Si_2O_6)$. The garnet ranges in color from orange to red to purple including most of the combinations between these. The ilmenite is invariably an opaque iron-black color and is usually magnetic.

Streams

The sampling of stream sediments was focused mainly on Ison Creek and Hamilton Creek. These are the major streams which drain their respective valleys. Both of these streams terminate by intersection with the Little Fork of the Little Sandy River. Samples were also taken from the Little Fork, but no garnet or diopside was found in any of the Little Fork samples. Ilmenite was present in extremely minute amounts which were too difficult to separate by mechanical means from the rest of the sample. Therefore, the Little Fork is of little importance in the determination of the sedimentation patterns from the kimberlite outcrops.

Hamilton Creek follows an undefinable path from the point where it first receives kimberlite sediments to its end. The heavy minerals are transported from the outcrop area to Hamilton Creek by a small tributary stream. This stream receives water both from normal valley drainage and from a small pond which apparently was created during mining operations at this particular outcrop. Upstream from the point of intersection, Hamilton Creek is almost non-existent. Immediately downstream from this point, it loses its well defined channel and flows partly on the adjacent dirt roadway. About one hundred yards east of the intersection of the two streams, it again follows a defined channel. At this point, the discharge of the stream was measured and found to be 0.414 cubic feet per second (Fig. 3 and Plate 2-A). Another discharge measurement was taken about half way between the intersection of the tributary and Hamilton Creek and the intersection of Hamilton Creek and the Little Fork. At this point the discharge was 0.660 cubic feet per second (Fig. 4 and Plate 2-B). From this point to the end of Hamilton Creek, the stream is disrupted as it flows through marshy pastures. All signs of a well defined channel are gone. Only once, near the junction of Hamilton Creek and the Little Fork do the waters of Hamilton Creek regroup as they leave the pasture area and enter the Little Fork. Hamilton Creek contributes relatively little water to the

Fig. 3. Hamilton Creek at the site of the first measurement of discharge.

Fig. 4. Hamilton Creek at the site of the second measurement of discharge.

Little Fork. This is shown by comparing the last discharge on Hamilton Creek (0.660 cfs.) with the discharge just down-stream from the junction of the two streams, measured at 24.31 cubic feet per second (Fig. 5 and Plate 2-C). Location of stream measurements are shown on the accompanying map (Plates 3).

Fig. 5. Site of a discharge measurement on the Little Fork of the Little Sandy River.

Ison Creek follows a well defined channel except for one area where it enters a marsh and is divided into many small streamlets which appear and disappear at various intervals in the thick grass. The heavy minerals are transported from the main source by ephemeral streams. At the junction of the main ephermal stream valley and Ison Creek, Ison Creek is already a substantial stream, approximately eight feet wide and six to ten inches in depth. It flows in this manner for about 1.25 miles until it enters the marsh. It leaves the marsh and is joined by Johnson Creek. A measurement taken not far from the main source shows a discharge of 1.18 cubic feet per second (Plates 2-D). After the entrance of Johnson Creek, the discharge increases to 2.61 cubic feet per second (Fig. 6 and Plate 2-E). With the addition of Squirrel Run's

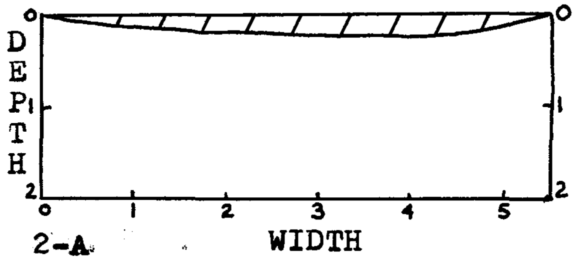
Fig. 6. Site of a discharge measurement on Ison Creek. A typical view of Ison Creek.

water to Ison Creek, the discharge increases to 7.08 cubic feet per second (Plate 2-F). The stream continues unimpeded until it joins with the Little Fork.

Sediments from the lesser outcrops of kimberlite in Ison Creek Valley are transported about 0.25 miles by ephemeral streams to Ison Creek. On the day the streams were measured,

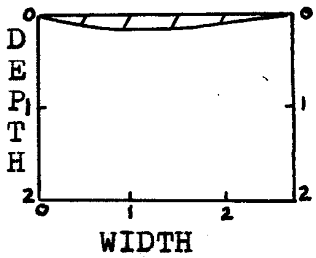
Stream Profiles

Width measured in Feet
Depth measured in Feet

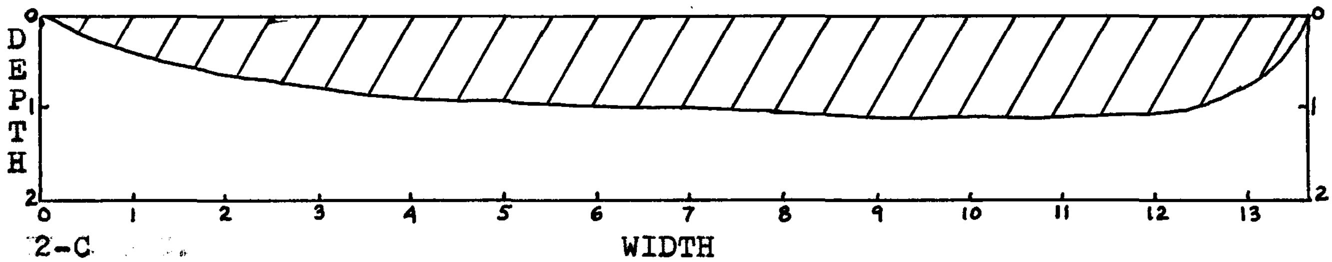


2-A

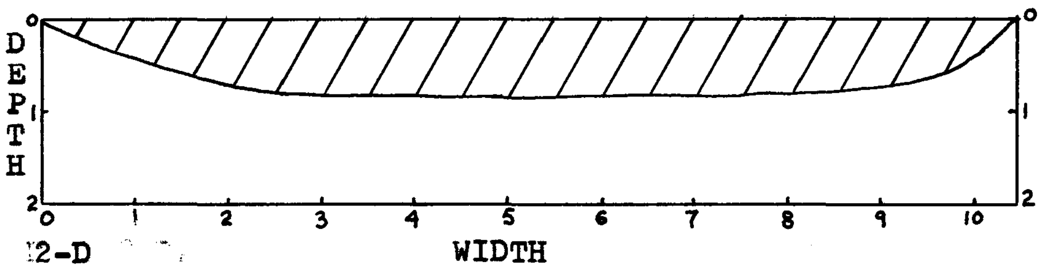
Plate 2



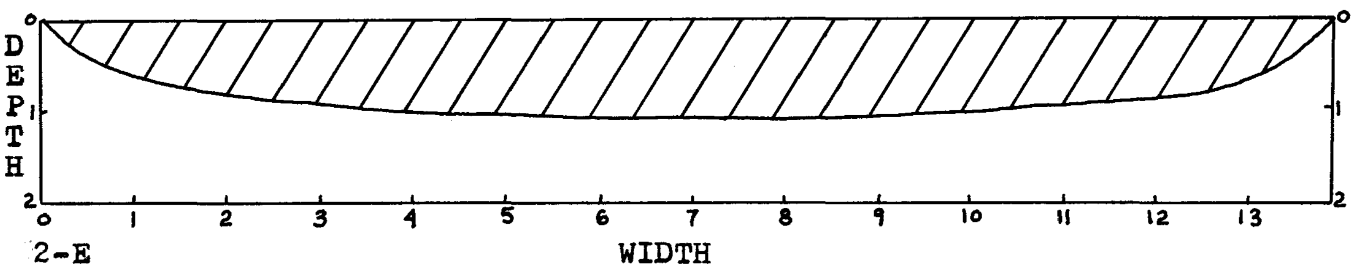
2-B



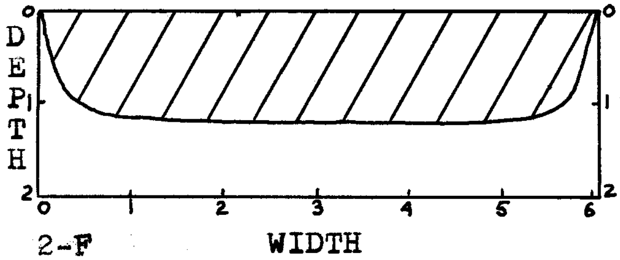
2-C



2-D



2-E



2-F

there was no water in either of these streambeds. It is significant to note that the streams were measured in mid-April following two weeks of rainy weather.

Procedure

Samples were taken at various intervals from the three streams and taken to a lab for processing. In the lab, the samples were washed in a 0.061 mm. sieve to rid them of unwanted fine silt and clay. The remainder of each sample was then separated into various grain size categories by sieving. All but the 0.061 mm., 0.125 mm., and 0.250 mm. size grains were placed in storage. Each of the samples in the remaining three size ranges was split until a convenient size for processing was reached. After weighing, the samples were run through a Franz Isodynamic Separator at a setting of 1.4 amps., a forward slope of 15°, and a side slope of 15°. This separated most of the quartz grains from the samples. The quartz, or non-magnetic portion, was stored, while the magnetic portion was further separated by floating off the light minerals in heavy liquids (1,1,2,2 tetrabromoethane). The heavy portion, containing the ilmenite, garnet, and diopside was then re-run through the Franz Isodynamic Separator at a setting of 0.4 amps. at the same slope settings as the earlier run. The non-magnetic portion then contained the garnet and diopside grains, while the magnetic portion contained the ilmenite grains. The garnet and diopside grains were then hand picked from the remaining extraneous material. Finally, the ilmenite, garnet, and diopside were weighed on an analytical balance and the percentage of each in the original sample was calculated.

Sediment Dispersal from the Kimberlite Point Source

Samples of the bottom sediments were taken from Ison Creek, Hamilton Creek, and Little Fork of the Little Sandy River. The locations from which the samples were taken are shown on the accompanying map (Plate 3). The minerals ilmenite, garnet, and diopside, for reasons explained in an earlier discussion of the kimberlite intrusions, were mechanically separated from the rest of the sample, which consisted chiefly of quartz grains and muscovite from the micaceous sandstone of the Breathitt Formation. An excellent separation was achieved for both garnet and diopside. However, due to the magnetic properties of various associated grains, ilmenite could not be completely separated from the sample using the Isodynamic Separator. This does not mean that a valid pattern cannot be discerned for the deposition of ilmenite in these streams. More refined methods could probably completely separate the "junk" from the ilmenite, but by using standardized lab procedures for each sample, any change in a graph of percentage of ilmenite versus distance from the source would be one of amplitude and not of the relationships between the points on the graph.

Each sample was divided into three segments according to grain size so that a comparison of the effects of grain size on the dilution of the desired minerals with distance from the source could be made.

For each mineral, graphs of its percentage of the total sample versus its distance from the source can be constructed in each size range (because of the problems inherent in separating such small grains of garnet and diopside from the sample, only ilmenite will be discussed in the 0.061 mm. size category). In this section, an analysis will be made of each of these graphs and an attempt will be made to show relationships between them.

First to be considered will be those patterns found in the sediments of Hamilton Creek; specifically, the pattern found for garnet in both size categories. Fig. 7 demonstrates what will soon be apparent as the trend in most of the graphs, a rapid increase in percentage of garnet of 0.125 mm. size until a distance of one thousand to two thousand feet from the source. Then there is a sharp decline so that at the three thousand foot distance the percentage of garnet has dropped off to about one seventh of what it was a thousand feet closer to the source. The rate of dilution of the garnet in the sample declines rapidly and reaches a rate which remains almost constant until the garnet disappears altogether from the sample. The rate of change in percentage, or rate of dilution, can easily be calculated for any of these graphs with the simple equation RATE OF CHANGE = dy/dx. The garnet of 0.125 mm. size begins with a lower percentage and ends at a farther point from the source than the 0.250 mm. size (Fig. 8). This can be explained by the fact that the grains near the source have had fewer chances to be broken into smaller pieces since they have not been transported and bounced around as much by the stream. It requires more energy to transport the larger and

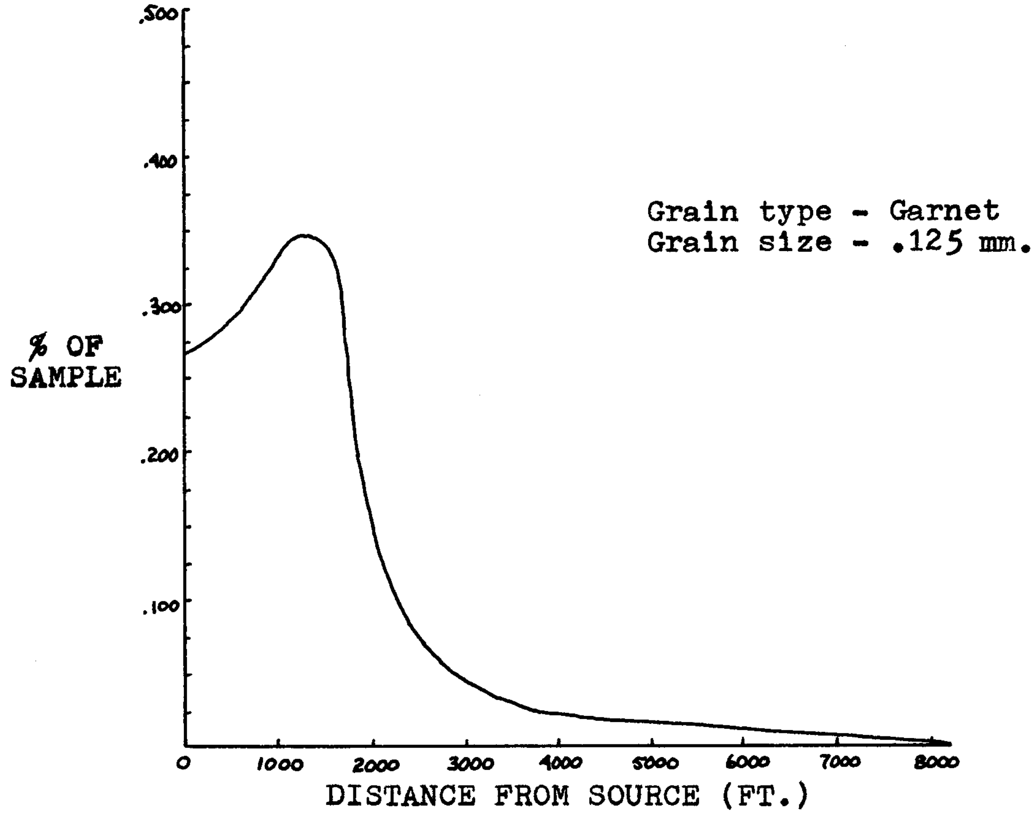

.500
.400
.300
.200
.100
% OF SAMPLE
Grain type - Garnet
Grain size - .125 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
DISTANCE FROM SOURCE (FT.)

Fig. 7.

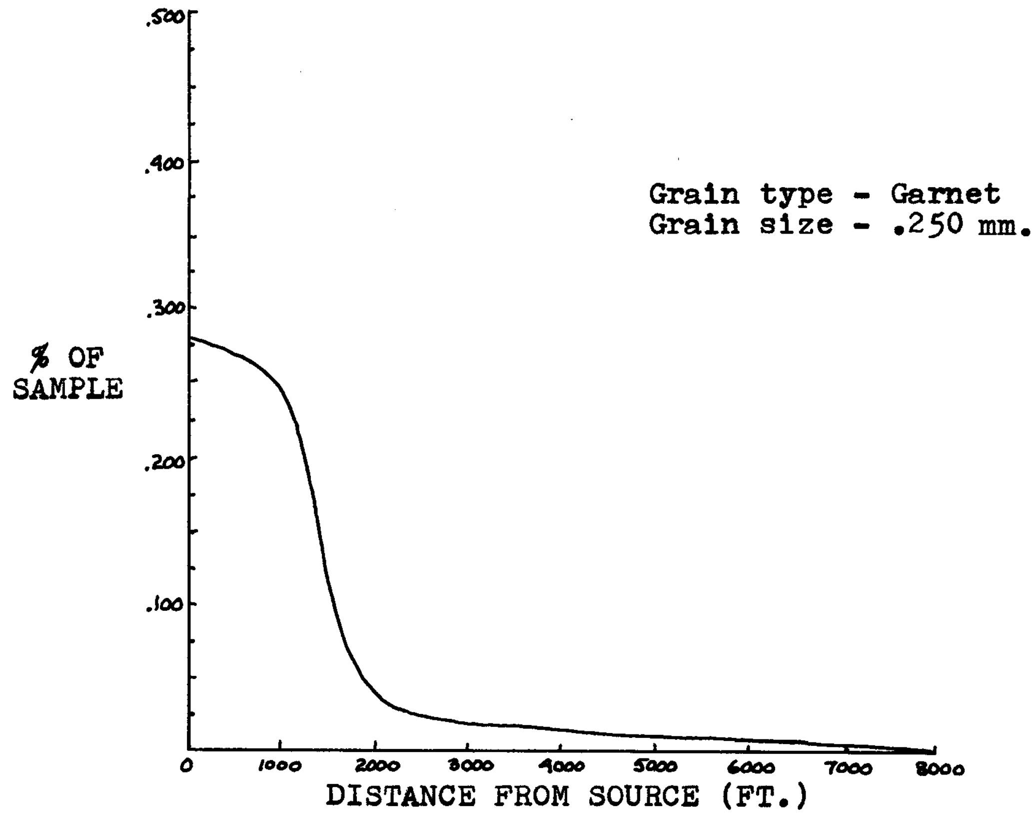

.500
.400
.300
.200
.100
% OF SAMPLE
Grain type - Garnet
Grain size - .250 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
DISTANCE FROM SOURCE (FT.)

Fig. 8.

heavier grains an equal distance as the small grains. Therefore, with the same amount of energy at work on all size particles, the smaller particles will be carried the greatest distance. That this is actually the case, is seen in almost all of the graphs. Exceptions to this case must be explained by examining obstacles to this pattern. Fig. 8 shows that the 0.250 mm. garnets are an exceptional case in Hamilton Creek Valley. As was stated in the discussion of Hamilton Creek, the stream at its intersection with the main tributary valley is very erratic. Flowing on the roadway at one point, in a ditch at another, and through a grassy area at another, it is conceivable that the stream dropped the larger grains of garnet at scattered locations and thus contributed to the dilution of garnet in the sample, which were taken at the points which most resembled a streambed.

Fig. 9 and Fig. 10 show the patterns for diopside in the 0.125 mm. and 0.250 mm. grain size, respectively, in Hamilton Creek. A remarkable resemblance exists between these graphs and the graphs for 0.125 mm. and 0.250 mm. garnet, except for a decrease in amplitude on the diopside graphs. The larger diopside grains are more abundant nearer the source than the smaller grains. This, again, results from being less broken up due to less transportation by the stream. The smaller grains are abundant at the one thousand foot distance for two reasons. First, this is the distance which the erosional forces have been able to overcome for the majority of the particles of this size since the exposure of the outcrop or since the stream adopted this path, whichever happened the

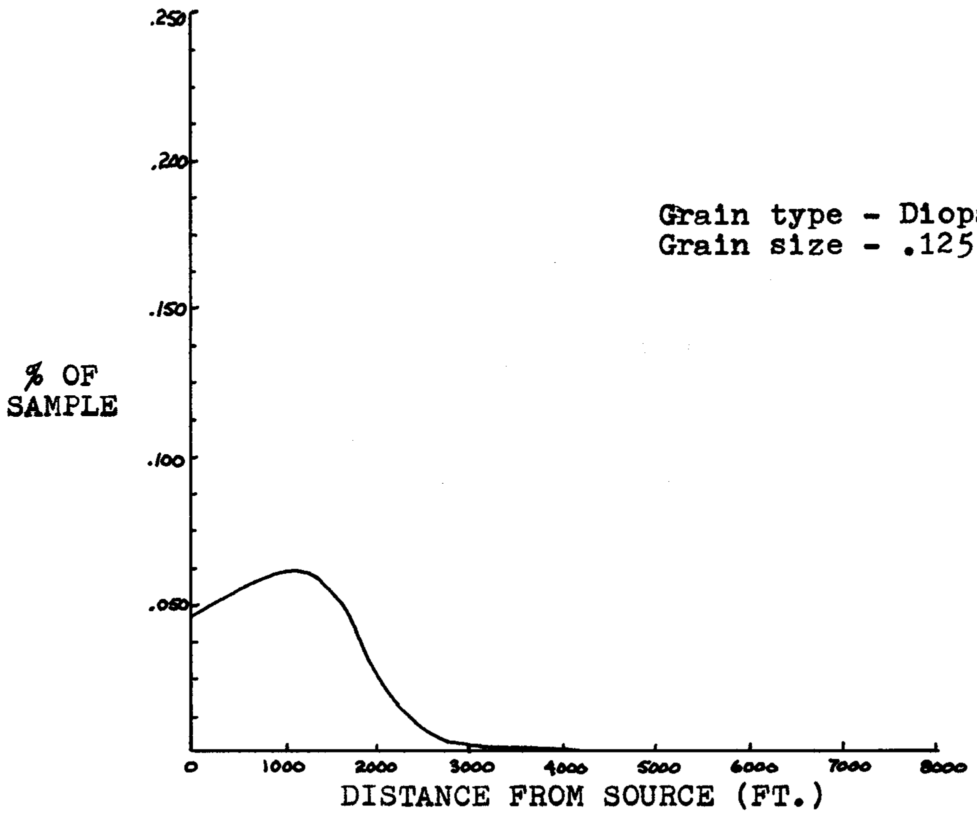

.250
.200
.150
.100
.050
% OF SAMPLE
Grain type - Diopside
Grain size - .125 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
DISTANCE FROM SOURCE (FT.)

Fig. 9.

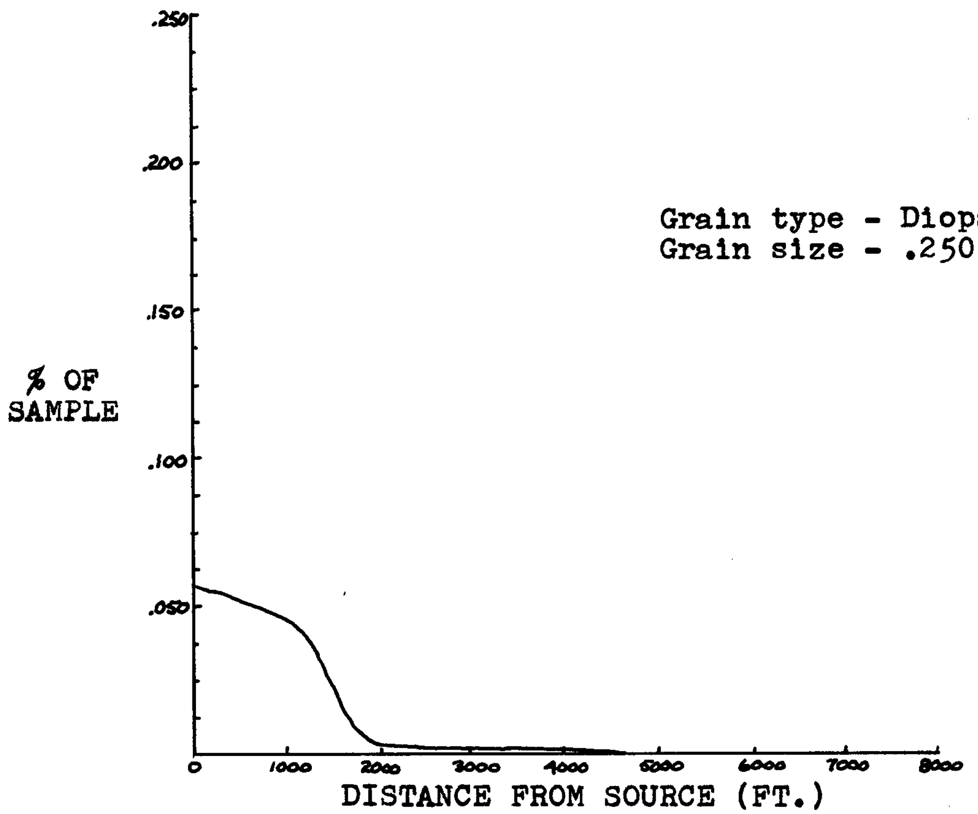

.250
.200
.150
.100
.050
% OF SAMPLE
Grain type - Diopside
Grain size - .250 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
DISTANCE FROM SOURCE (FT.)

Fig. 10.

most recently. Second, the larger particles tend to break-down into particles of a smaller size as soon as they are bounced around in the streambed. This causes additional material of the 0.125 mm. size to be added at this point to the 0.125 mm. grains which have escaped breaking up and were carried this distance in their present form. The smaller grains of diopside, like the smaller grains of garnet, travel the longer distance. The 0.250 mm. diopside grains show a similar pattern to the 0.250 mm. garnet. The explanation for this is probably the same as for the pattern of the garnets and need not be explained further.

Ilmenite was studied in the 0.061 mm. size, as well as the other sizes. Fig. 11, Fig. 12, and Fig. 13 show the patterns of occurrence of this mineral in Hamilton Creek. These patterns conform almost perfectly to the "ideal" case specified in the discussion of garnets. The 0.061 mm. graph has a lower amplitude than either the 0.125 mm. or 0.250 mm. graphs, and the 0.125 mm. graph has an amplitude lower than the 0.250 mm. graph. The 0.061 mm. pattern has a lower than or equal amplitude to the 0.125 mm. pattern at all distances up to eight thousand feet. At this distance the 0.061 mm. grains predominate while the larger ilmenite grains decline in their frequency of appearance. The exceptionally high amplitudes for ilmenite are a result of the relatively high amount of ilmenite in the kimberlite as compared to the amount of garnet and diopside it contains. No measurable amounts of ilmenite were found in the Little Fork.

In Ison Creek, the 0.125 mm. and 0.250 mm. garnets repeat

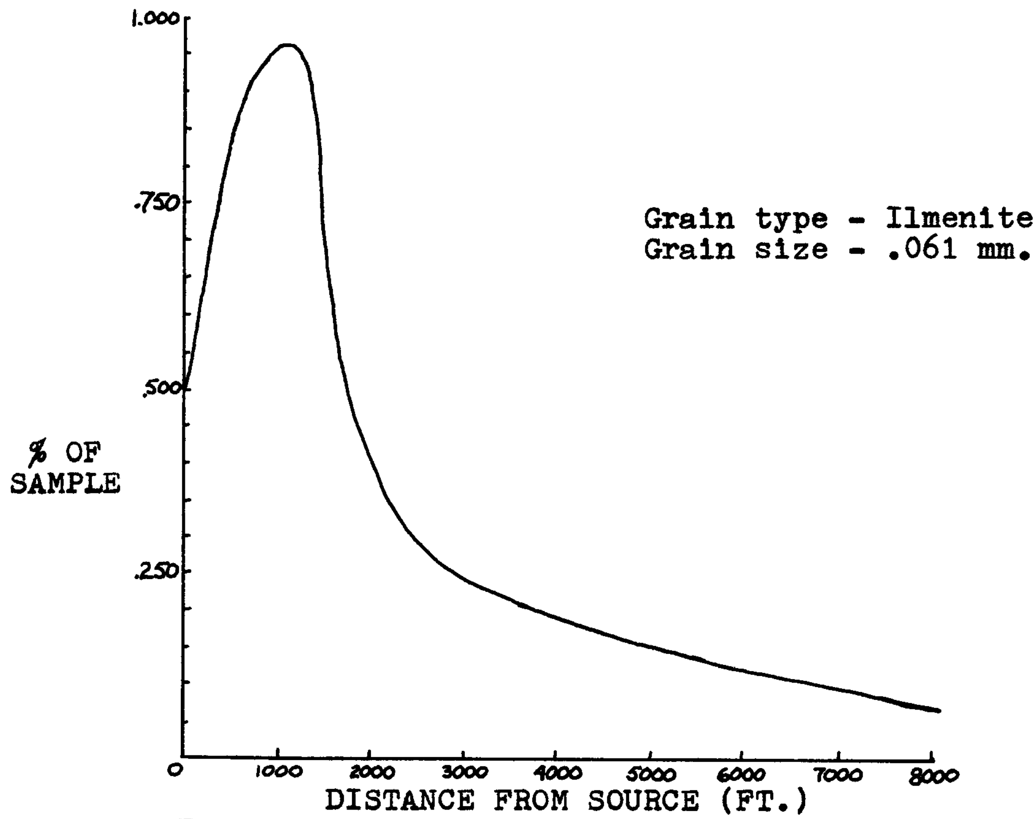

1.000
.750
.500
.250
% OF
SAMPLE
Grain type - Ilmenite
Grain size - .061 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
DISTANCE FROM SOURCE (FT.)

Fig. 11.

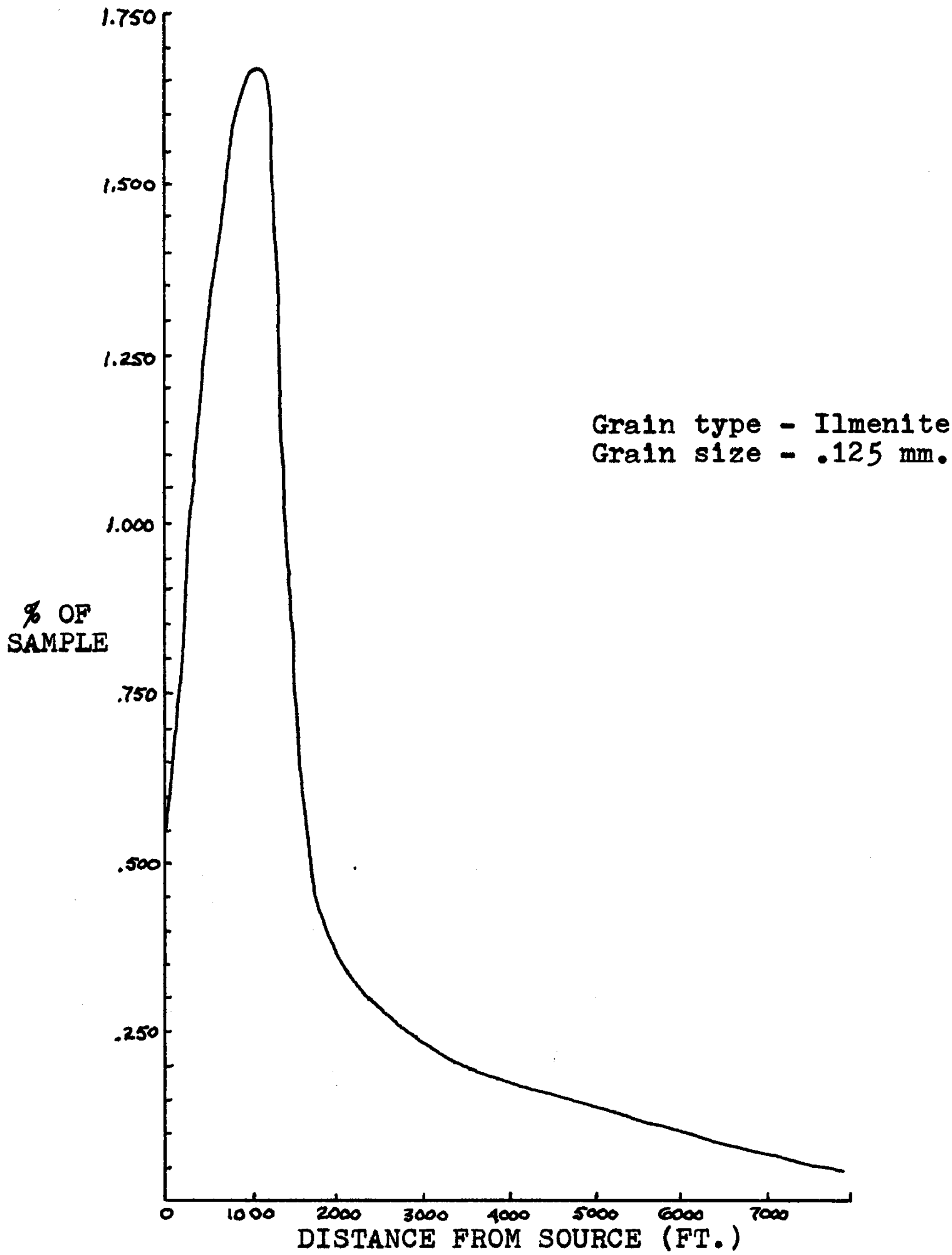

1.750
1.500
1.250
1.000
.750
.500
.250
% OF SAMPLE
Grain type - Ilmenite
Grain size - .125 mm.
0
1000
2000
3000
4000
5000
6000
7000
DISTANCE FROM SOURCE (FT.)

Fig. 12.

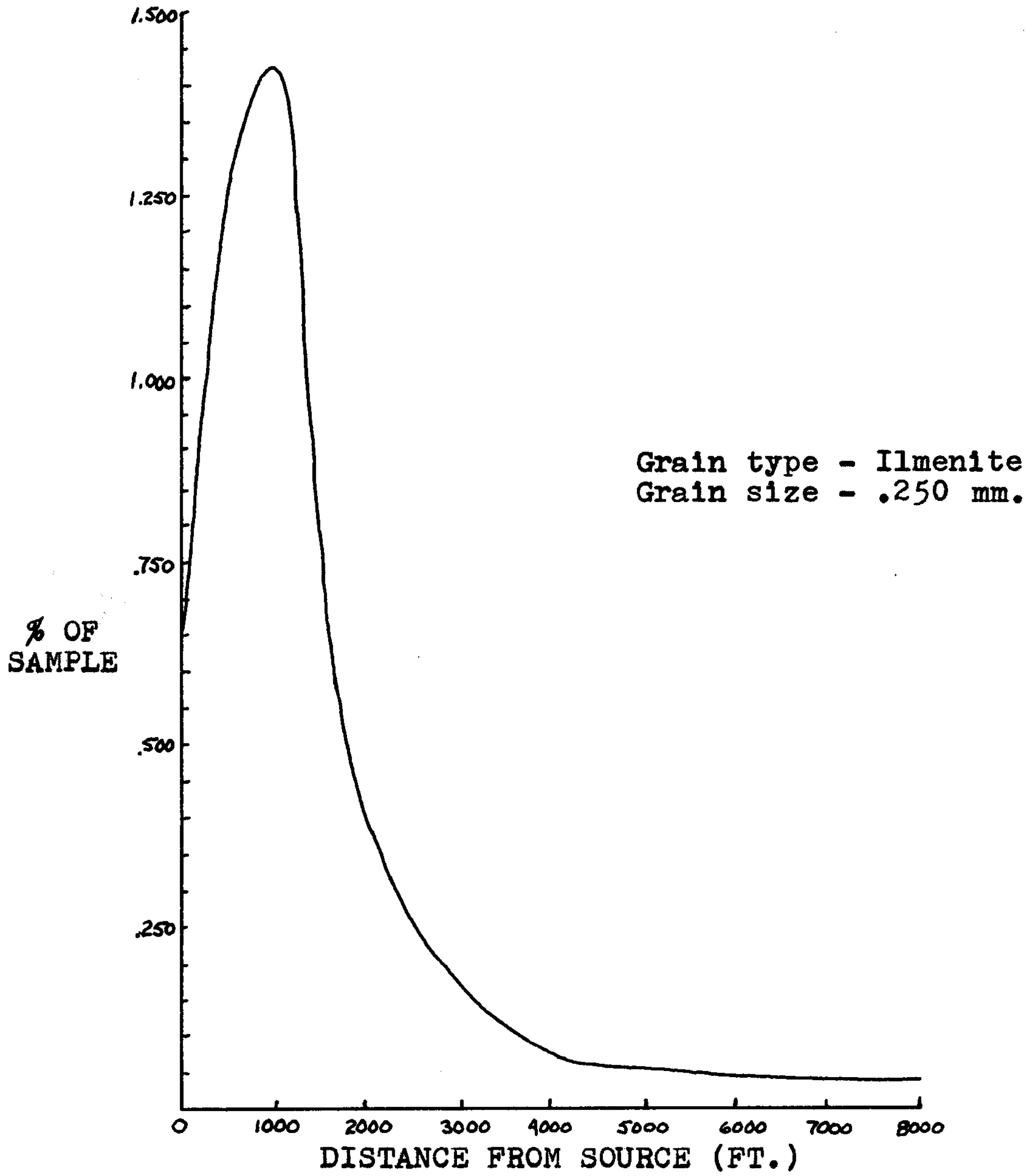

1.500
1.250
1.000
.750
.500
.250
% OF
SAMPLE
Grain type - Ilmenite
Grain size - .250 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
DISTANCE FROM SOURCE (FT.)

Fig. 13.

the pattern (Fig. 14 and Fig. 15). The 0.125 mm. grains disappear at about ten thousand feet from the source, while the 0.250 mm. grains disappear at about eight thousand-five hundred feet. Compared to the patterns of the Hamilton Creek garnet grains, these grains are present in much smaller amounts, but the relationships between percentage present and distance are very close. No noticeable contribution was made to the amount of any of the three minerals in Ison Creek by the lesser tributary streams draining the areas of the two less important outcrops in Ison Creek Valley. The patterns for the 0.125 mm. and 0.250 mm. diopside (Fig. 16 and Fig. 17) are good examples of what might be compared to "phase shift." The leftward shift of the peak on the 0.250 mm. graph compared to the 0.125 mm. graph indicates that the area of the highest accumulation for larger particles tends to be closer to the source than the area of highest accumulation for smaller particles. This shift can be seen on several of the graphs. The comparison between the graphs for diopside in Ison Creek Valley and Hamilton Creek Valley is not a very close one. This is attributable to the differences in the two streams. Hamilton Creek is an erratic, undependable stream, whereas Ison Creek is a stream of a more constant nature and a larger discharge.

The patterns for ilmenite exhibit most of the idealistic qualities discussed with the other mineral patterns in both Ison Creek and Hamilton Creek (Fig. 18, Fig. 19, and Fig. 20). The larger grains are more abundant nearer the source than the smaller grains. As the distance increases, the smaller grains

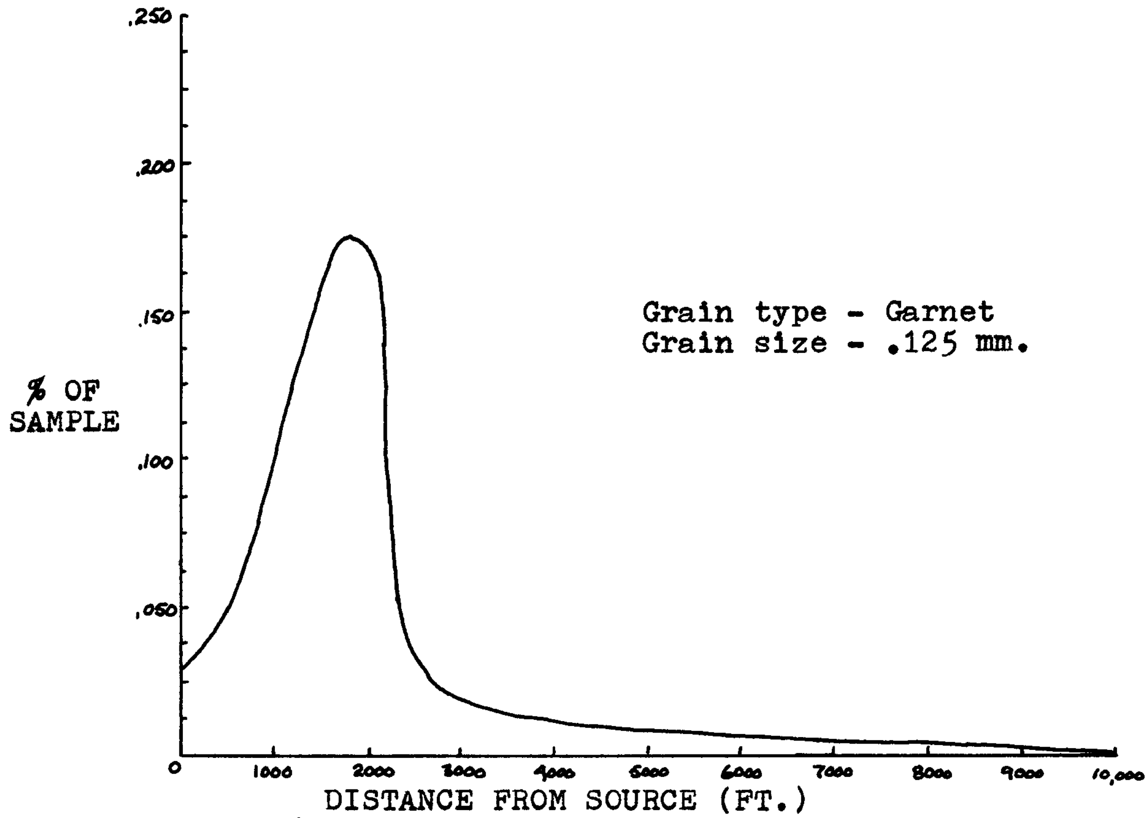

.250
.200
.150
.100
.050
% OF
SAMPLE
Grain type - Garnet
Grain size - .125 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISTANCE FROM SOURCE (FT.)

Fig. 14.

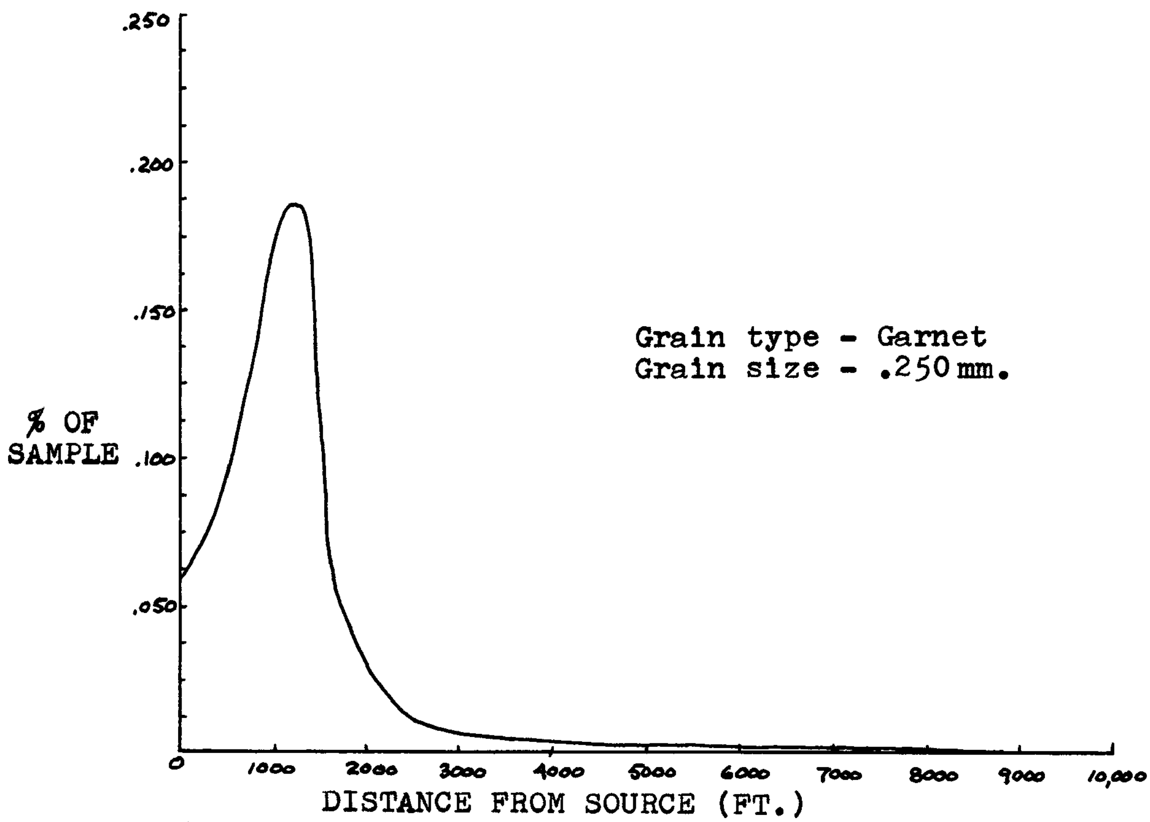
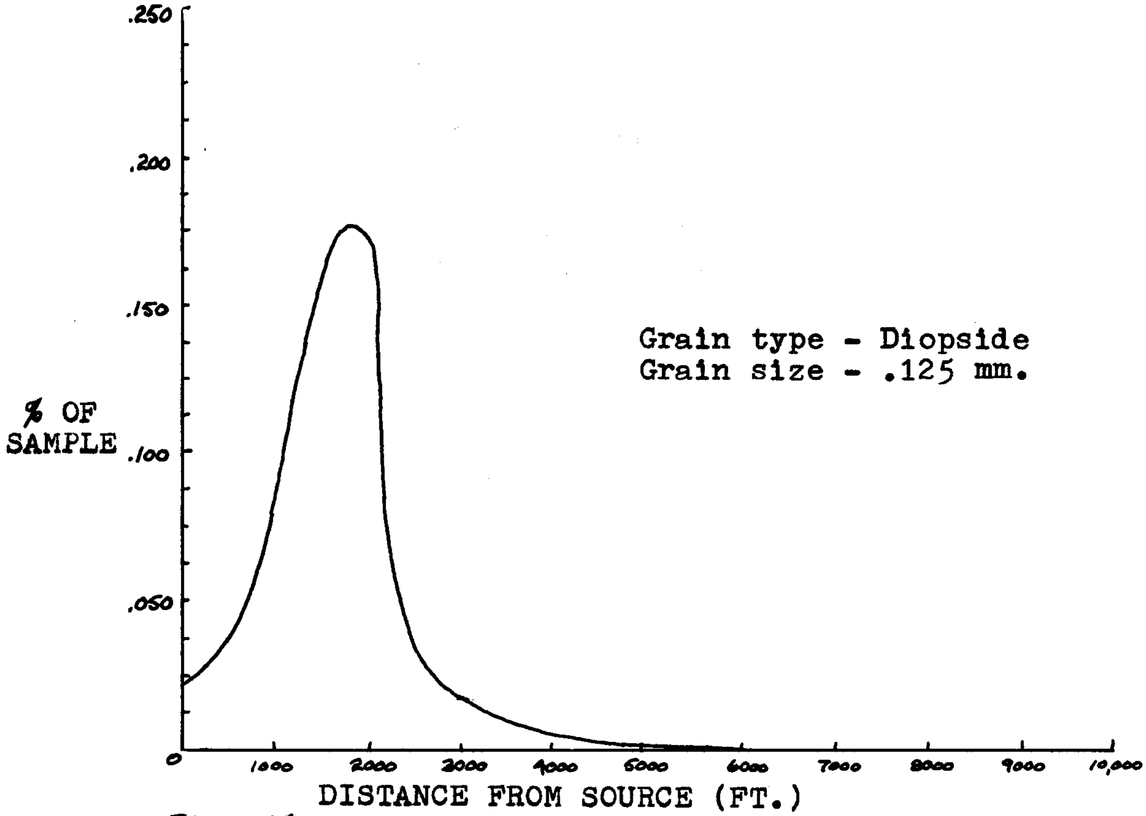
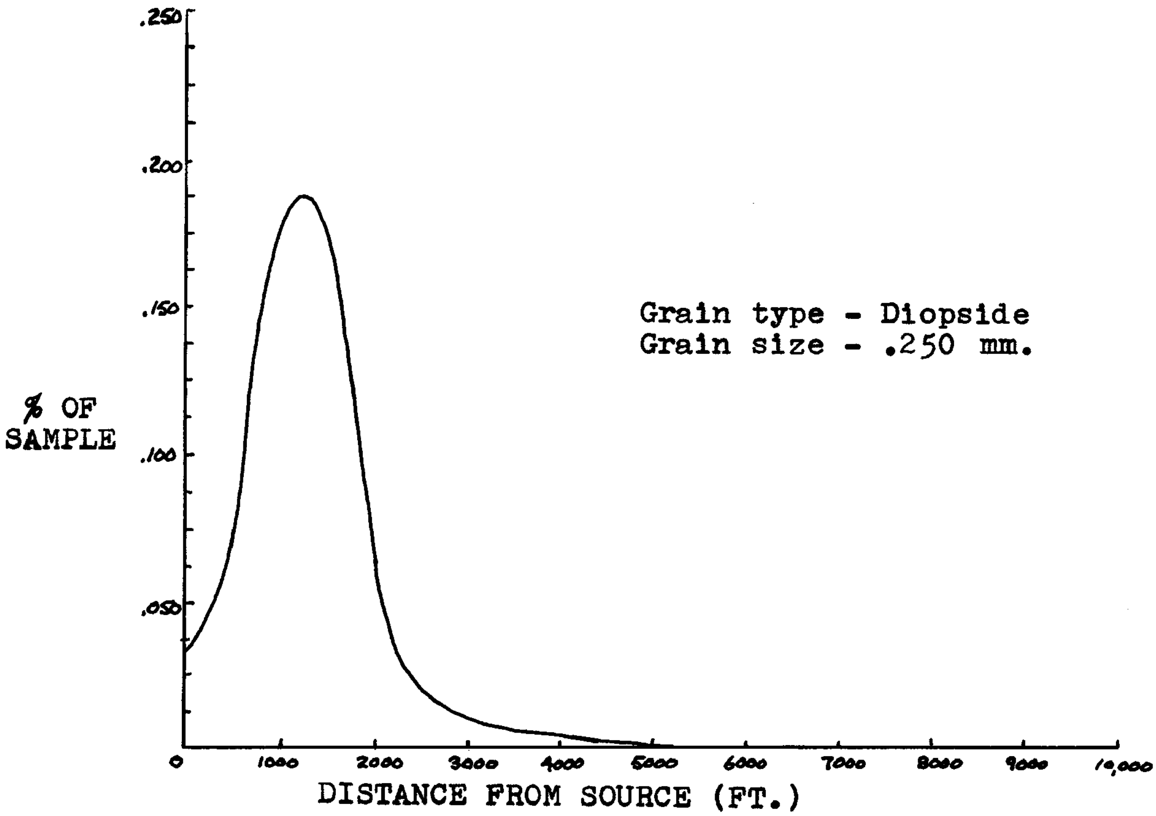

.250
.200
.150
.100
.050
% OF
SAMPLE
Grain type - Garnet
Grain size - .250 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISTANCE FROM SOURCE (FT.)

Fig. 15.



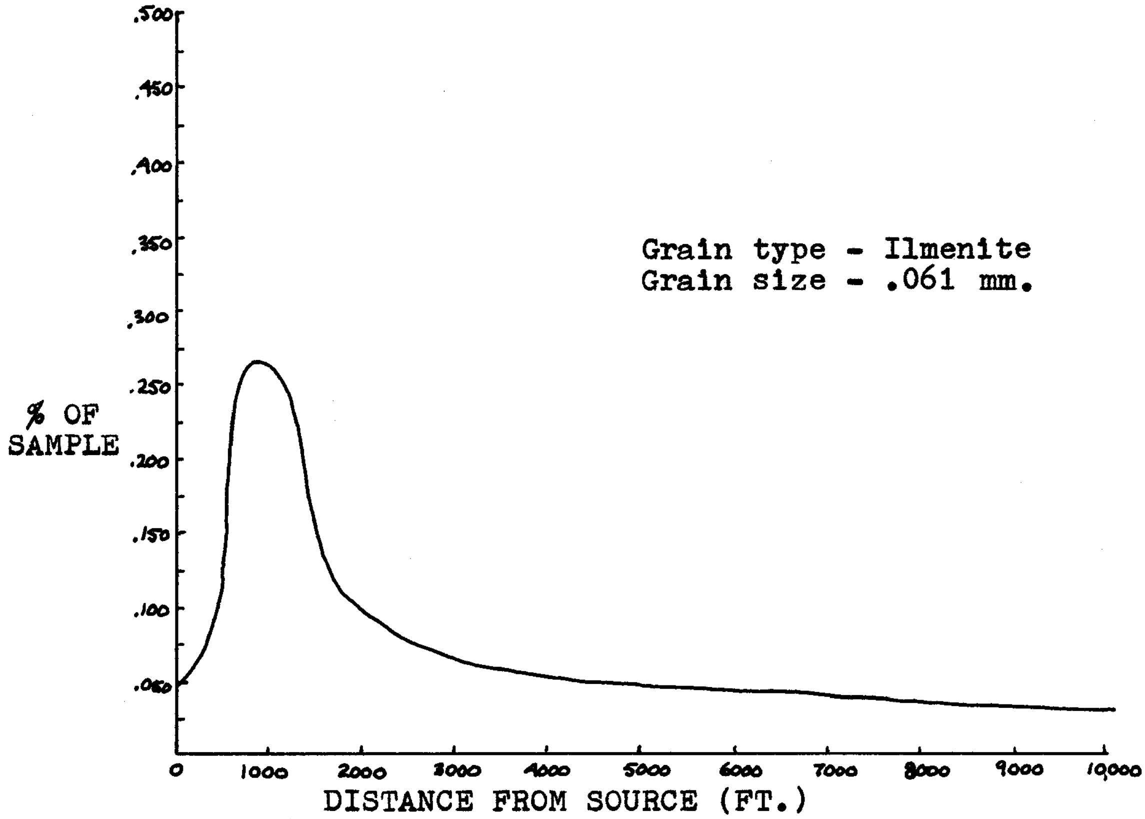
.250
.200
.150
.100
.050
0
% OF SAMPLE
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISTANCE FROM SOURCE (FT.)
Grain type - Diopside
Grain size - .125 mm.

Fig. 16.



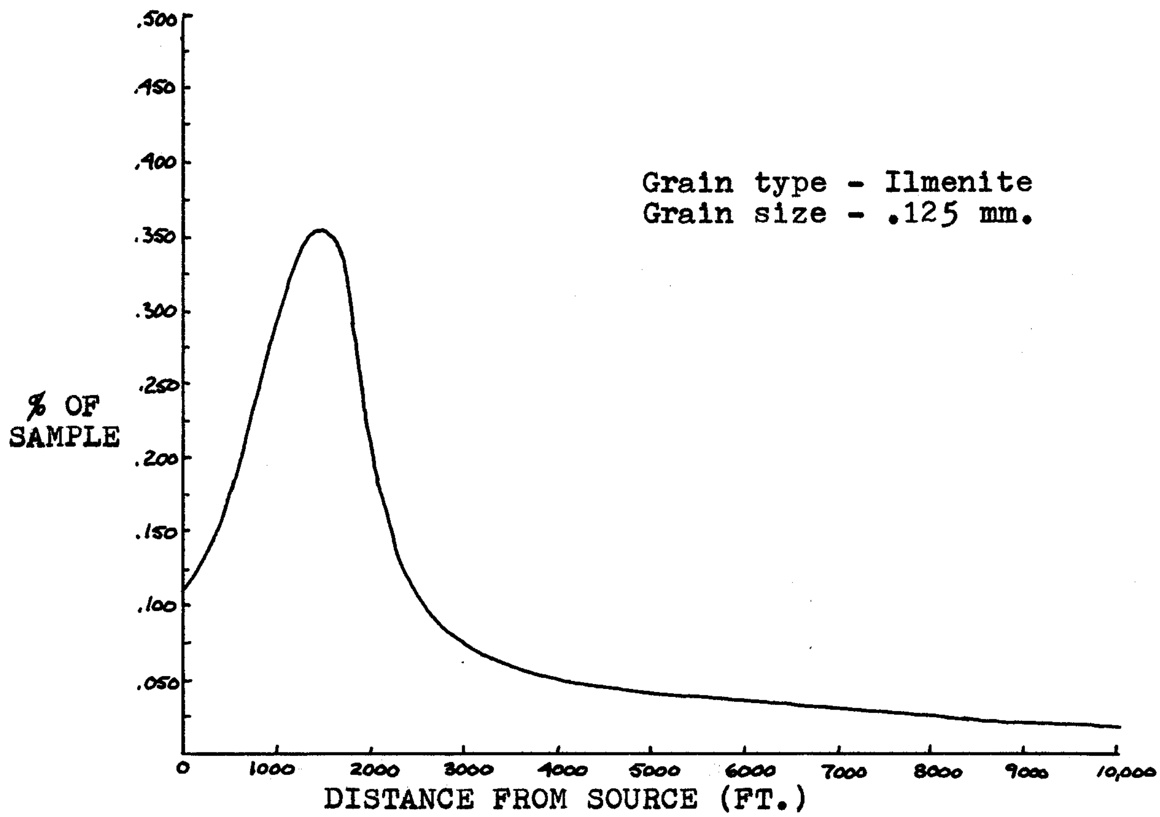
.250
.200
.150
.100
.050
0
% OF SAMPLE
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISTANCE FROM SOURCE (FT.)
Grain type - Diopside
Grain size - .250 mm.

Fig. 17.



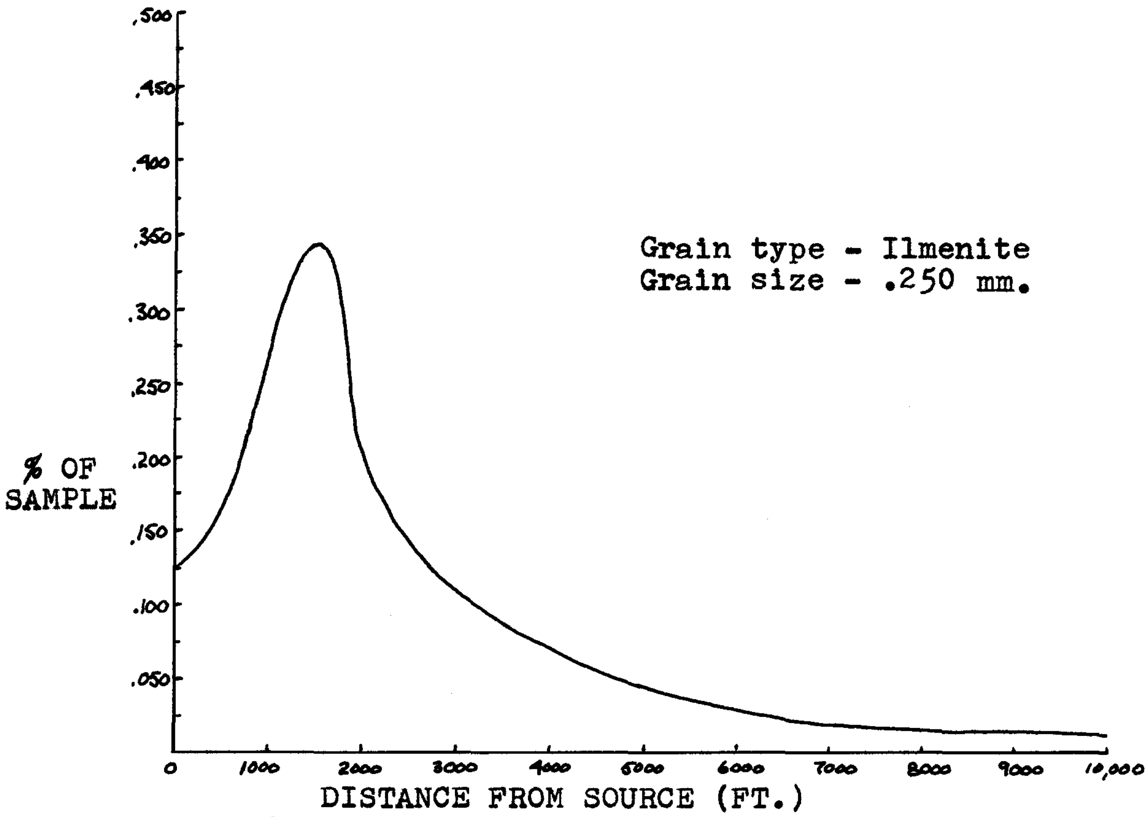
.500
.450
.400
.350
.300
.250
.200
.150
.100
.050
% OF SAMPLE
Grain type - Ilmenite
Grain size - .061 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISTANCE FROM SOURCE (FT.)

Fig. 18.



.500
.450
.400
.350
.300
.250
.200
.150
.100
.050
% OF SAMPLE
Grain type - Ilmenite
Grain size - .125 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISTANCE FROM SOURCE (FT.)

Fig. 19.



.500
.450
.400
.350
.300
.250
.200
.150
.100
.050
% OF SAMPLE
Grain type - Ilmenite
Grain size - .250 mm.
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISTANCE FROM SOURCE (FT.)

Fig. 20.

become more abundant relative to the larger grains. At ten thousand feet the 0.061 mm. grains of ilmenite are more than twice as abundant as the 0.250 mm. grains.

Relationships of Discharge and Sedimentation

The relationship between discharge and sedimentation which is most apparent in each valley is that Ison Creek, with the higher discharge, will usually carry particles farther than Hamilton Creek, with a lower discharge. Variations in the shape of the streambed seem to play an important role in the dispersal of large grained sediments in Hamilton Creek, as shown by the anomalous patterns of 0.250 mm. garnet and diopside. But, the patterns of the smaller grains were unaffected by the erratic stream channel. In both valleys, similar patterns do exist. Differences in these patterns, other than the one exception already cited, are the result of the amount of material being supplied from the source and the amount of energy being used to move the material downstream.

Possible Use for Prospecting

With certain limitations in mind, it can be said that a knowledge of the heavy mineral sedimentation patterns of the streams in the area could lead to the discovery of yet unknown outcrops of kimberlite. Of course, this need not be limited to this particular area. Similar patterns could exist anywhere. If detailed studies were carried out to determine the relationships between the patterns and many various discharges which cause these patterns, then the patterns could be used as an accurate tool for locating the source body. As an ultimate step, it is conceivable that segments of a pattern, resulting from limited sampling of a stream, could be read into a computer which would compare this pattern segment with an "average pattern" for the given stream discharges and receive from the computer a fairly accurate determination of the distance to the source.

A limitation to this process would be that ilmenite could not be used accurately for the patterns unless it was completely separated from the "junk" minerals or unless the "junk" minerals are the same in every case so that they will contribute neither more nor less to patterns in different streams.

Another limitation is the necessity that an area has undergone erosional processes under the influence of a single continuous climatic environment. If this is not the case, then different patterns may be superimposed upon each other if the present erosional forces have not had time enough to remove the traces of the old pattern. If these limitations are taken into account and adjusted for, the use of sediment dispersal patterns could become as important prospecting procedure.